AdS/QCD and Nuclear Physics

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INTRODUCTION

AdS/QCD or Holographic QCD is a new approach to construct an effective theory for large N limit of QCD, by introducing additional space-like dimension roughly corresponding to energy scale of QCD processes. This idea is based on the observation that the large N QCD has a classical nature due to large N factorization of its gauge invariant observables, while the concept of RG running should still apply. Having a theory with additional space-like dimension can easily reconcile these two aspects. It realizes an old idea of dual string model of large N QCD in a very concrete level, but the necessity of having extra space dimension to consistently implement the idea is a ground breaking development in recent years, called AdS/CFT correspondence [1]. The original proposal of this AdS/CFT correspondence was for a highly special supersymmetric gauge theory, and recently there have been many activities trying to extend this correspondence to more realistic theories, such as QCD.

The first proposed models of holographic QCD, such as Sakai-Sugimoto model [2] and Hard Wall AdS/QCD model [3], mainly focused on the chiral dynamics of mesons and their spectrum. They had some degree of success in comparing with experiments up to 10-20%, which one normally expects from 1/N expansion. This is a stimulating result indicating both the potential of the methodology and the room for possible improvement of it.

NUCLEONS IN HOLOGRAPHIC QCD

As baryons are integral part of QCD, it is pertinent to study baryons, especially lowest mass nucleons, in the holographic approach of QCD. With collaborations with a nuclear theorist Mannque Rho and high energy physicists Deog Ki Hong and Piljin Yi, we initiated studying static properties of nucleons as well as their chiral dynamics with mesons in the Sakai-Sugimoto model [4], and our results can explain observed properties of nucleons successfully, such as the axial coupling to mesons, anomalous magnetic dipole moment, and electromagnetic form factor of nucleons [5], for example. Within our framework, many other questions that may be interesting to subnuclear and nuclear physics can be studied, such as nucleon-nucleon potential with nontrivial momentum transfer, etc.
This is a newly developed tool for studying QCD and nucleons that complements other existing theoretical models.

We also implemented nucleons in the framework of Hard Wall AdS/QCD model [6] in collaboration with Takeo Inami. Our model is including chiral symmetry breaking effects carefully, and in this respect it is an improvement of the previous model by Brodsky and Teramond [7]. Within our model, we obtained several notable achievements; we naturally explained parity doubling spectrum of excited baryons [6], we calculated electric dipole moment of the neutron [8], and we also studied finite baryon density effect to chiral condensate [9]. This model has much room for further refinement and more nuclear physics can be studied in the framework.

WEAK-INTERACTIONS IN HOLOGRAPHIC QCD

Finally, in collaboration with a nuclear theorist Doron Gazit, we recently implemented the effective Fermi-type weak-interaction vertex in the framework of holographic QCD [10], both Sakai-Sugimoto and Hard Wall AdS/QCD. As our model enables one to study hadronic weak processes involving strongly coupled QCD with weak-interactions, it opens a new perspective in applications of holographic QCD to subnuclear and nuclear physics involving weak-interactions. As exemplar calculations, we analyzed neutron beta decay, charged pion weak decay as well as parity non-conserving (PNC) meson-nucleon couplings within our framework [10]. We expect its future applications to be much worth of studying.

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